Sri Lanka's Miocene Jaffna Formation Fractured & Karstic Limestone Aquifer: the Sole Source of Drinking Water in the Jaffna Peninsula

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This tropical coastal aquifer is the sole source of drinking water for the for the 120,000 people of Jaffna City and the 615,000 residents of the 850-square kilometer Jaffna Peninsula in coastal Sri Lanka (Figure 1) and is poorly studied. It is thin, with low permeability, and limited storage capacity. It is overused, and rapidly degraded from manmade pollution and natural seawater intrusion. The aquifer is a shallow, generally flat, weathered and karstic limestone, whose few outcrops have mostly have been removed to create more agricultural land.

Because it is relatively young, even though the climate is tropical there hasn't been sufficient time to create the huge caverns found in many other carbonate aquifers. Because it is not heavily faulted, its fractures are not well connected and its primary and secondary hydraulic conductivities are low. The aquifer receives most of its natural recharge during the Maha monsoon of November to December, and some during the gentle Yala monsoon in May to September. It is otherwise over-pumped during the long dry seasons and saturated during the monsoons. It also receives significant recharge from household sewage and seawater. It is heavily polluted by agricultural chemicals, leachate from garbage, industrial waste disposal, and septic tank seepage. Because of rising sea levels and uncontrolled seawater intrusion, it is becoming more and more saline.

Although the aquifer receives about 20 percent of the regional rainfall as groundwater recharge, it has a small storage capacity and cannot meet agricultural, industrial, municipal, and household water demand (the relevant climatic, aquifer, and demand parameters are summarized in Table 1 at the end of the article). Consequently, although most households have shallow hand dug or drilled boreholes for washing, cooking, and cleaning, and the National Water Supply and Drainage Board supply public water at public roadside stations located throughout much of the City, householders import their drinking water as purified bottled water. Many of the over 80,000 domestic wells have been developed by blasting the aquifer to increase its local permeability and water-storage capacity. The water wells are typically approximately up to 10 meters deep.

To counter municipal water scarcity, it is planned to build a 35,000-cubic meters per day seawater desalination plant at Peaqpuchqkadu, located 70 km southeast of Jaffna City's Central Business District. Construction of this plant will be funded by an Asian Development Bank (ADB) loan In addition, there are many small to very large schemes of constructed freshwater lagoons and surface water tanks for supplementing irrigation water. They include a planned six square kilometer by six meters high constructed water tank (3.63 billion cubic meter capacity) at the far southeast Elephant Pass in the Jaffna Lagoon (Figure 4), to be funded by the Sri Lankan Irrigation Department.

These engineering innovations are being undertaken to correct the municipal and irrigation freshwater deficits affecting the approximately 735,000 residents of Jaffna City and Peninsula.

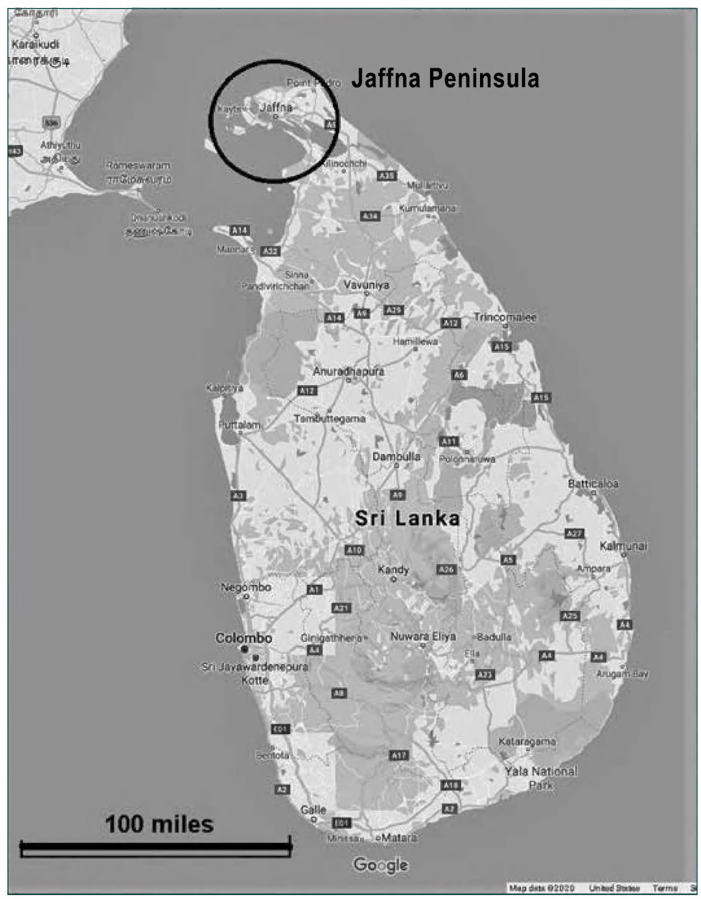

Figure 1 - The island nation of Sri Lanka. The city of Jaffna is circled. Courtesy Google Maps.

Figure 2 - Wall built of Jaffna Limestone, by D. Seevili as posted on Trip Advisor

Jaffna City or Town, also referred to as the Jaffna Municipal Council (JMC) extends 6 km east to west along the coast runs and 4 to 8.5 km inland. The Jaffna Lagoon and the Indian Ocean form the JMC's southwest and south boundaries, respectively (Figure 4). The highest elevation is 10 meters above sea level. There are no rivers or perennially flowing gullies within the city.

The management of the aquifer is much criticized due to its anthropogenic pollution and natural seawater contamination.

As there is no piped sewage collection in Jaffna City, raw domestic and industrial sewage from buried, near-surface septic tanks easily leaks directly to the underlying aquifer, from where it flows into canals. The 32.6 km of main drains; 30.4 km of submain drains; 50 km of other drains, 43 stormwater detention ponds, and 8 sea-outlets also recharge the aquifer with untreated sewage (Figure 5).

However, there are "honey wagons" (Figure 6) which collect some wastewater for anaerobic treatment and land application at the Jaffna City solid waste management facility at Kallundai, 6.5 kilometers northwest of the Central Business District The facility includes wastewater treatment, composting, plastic and glass recycling, and slaughter house and solid waste landfilling.

In addition, only half of Jaffna City enjoys garbage collection and disposal service, so much garbage is burned and/or thrown into the mentioned canals and ponds, a further addition to the pollution of the aquifer. All the canals and ponds are polluted with garbage, construction debris, and trash vegetation; and at least ten ponds have been filled in as designated garbage dumps.

Moreover, because the local tropical soils are low-fertility coarse regosols and calcareous latosols, they drain rapidly with infiltration rates exceeding 42 centimeters per hour. To make them commercially productive for paddy and vegetable crops, the soils must be over-irrigated, heavily fertilized and treated with pesticide. Thus, agricultural chemicals extensively pollute the Aquifer. Greenhouse agriculture is not an option because of its cost and unsuitability for rice and field vegetables.

Tidal fluctuations in sea level, especially during the dry seasons when groundwater levels are low, and climate-change induced rising sea levels, naturally contaminate the aquifer. The solution to seawater intrusion would be a network of fresh groundwater recharge wells along the coast, which would be expensive and is likely not feasible.

Finally, as for all limestone aquifers, the groundwater is naturally hard from dissolved calcium carbonate which promotes adverse gastrointestinal health effects.

In summary, groundwater typically contains agricultural chemicals such as pesticides and fertilizers, solid waste and its leachate, and septage and raw sewage. All the water wells contain hard water, nitrates, and coliform bacteria. More than 50 percent of the wells produce high salinity water. Unfortunately, this pollution and contamination is irreversible.

The objective of my work was to lead a local team of consultants in preparing a stormwater drainage master- and procurement plan to be implemented for up to four million dollars (Figure 7). Because of the high extent of urbanization, flat coastal topography, and inadequately cascading gravity-driven canal, pond and sea-outlet network, the recommended engineering option of a network of pump lift-stations and large-diameter pipelines to the sea would require investment of at least $500 million.

Figure 3 - My Tamil maid Kamsda views our Jaffna House water well and pump house.

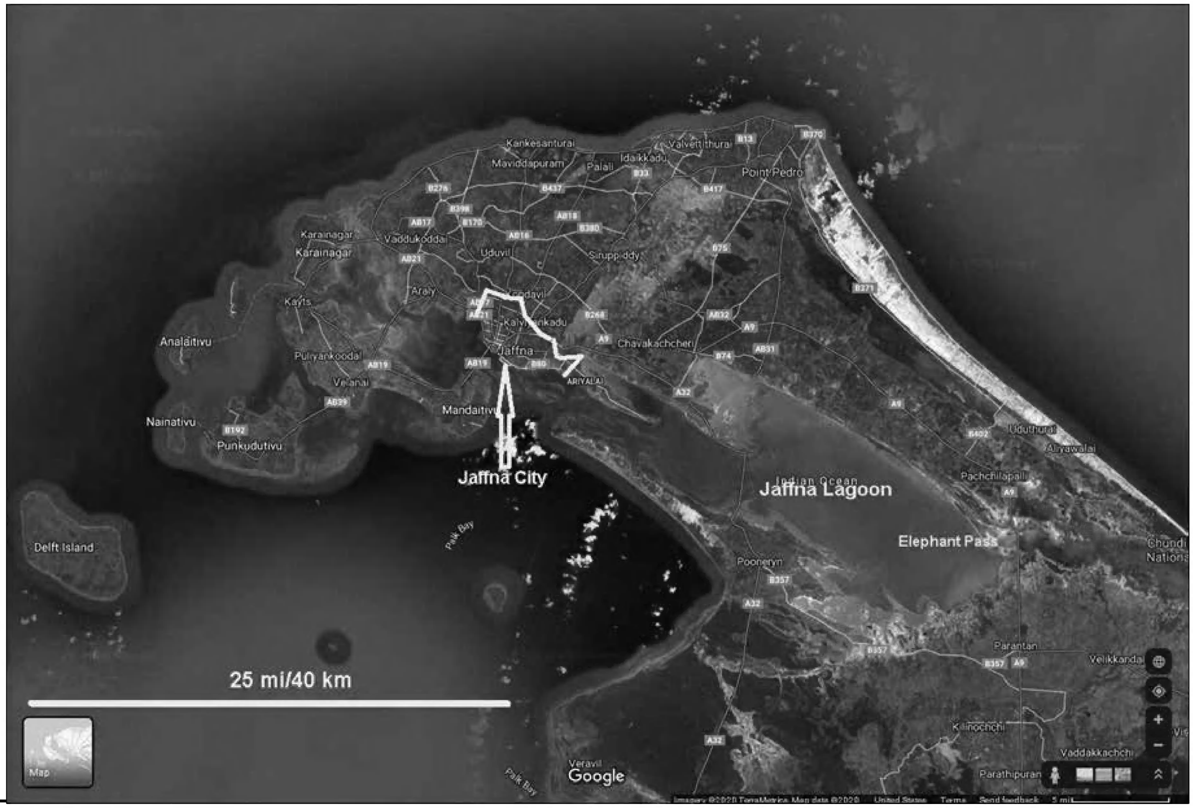

Figure 4 - Jaffna Peninsula showing Jaffna Lagoon, Elephant Pass, and extent of Jaffna City.

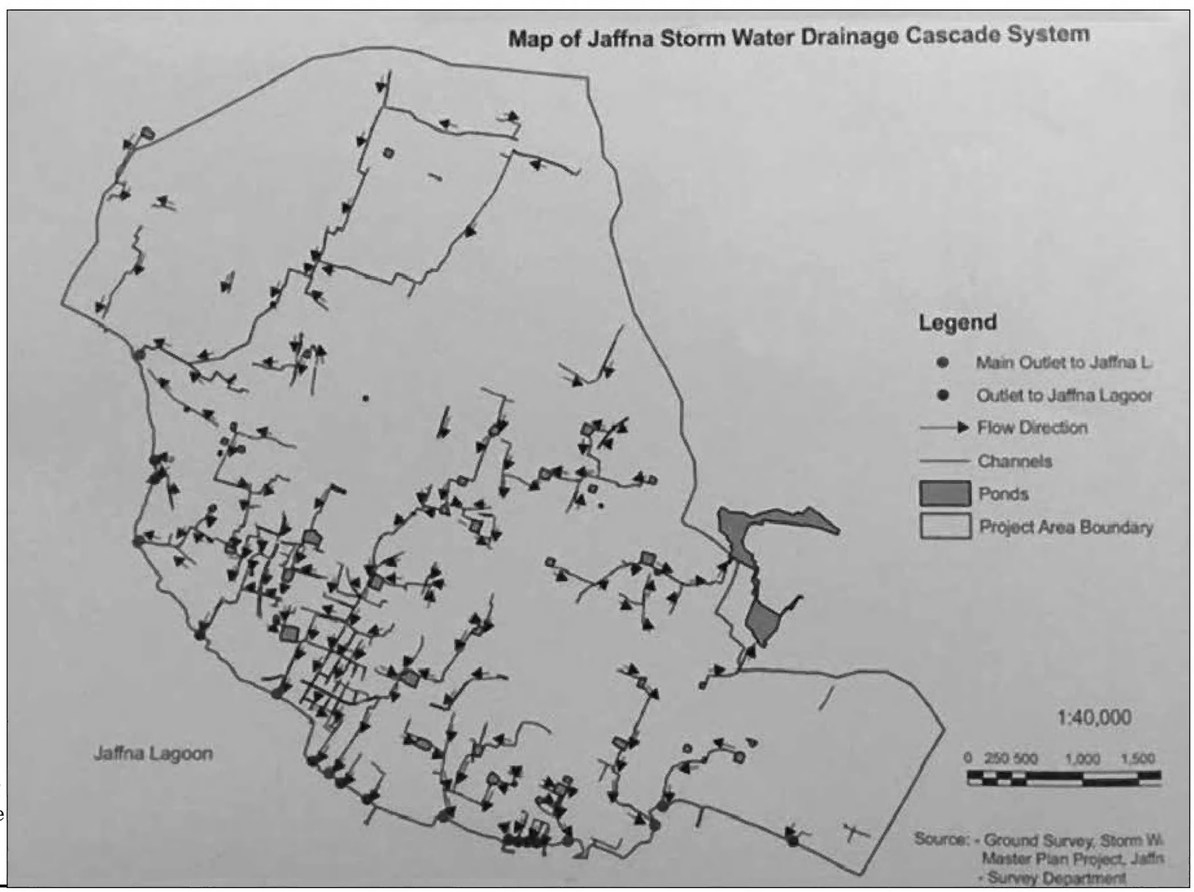

Figure 5 - Jaffna Peninsula Cascading Stormwater Drainage Canals, Ponds, and Sea Outlets.

Figure 6 - Left: My Tamil maid Kamsda and driver Shanker view the septic tank behind my bedroom/office of my house in Jaffna; Right: JMC "Honey Wagon."

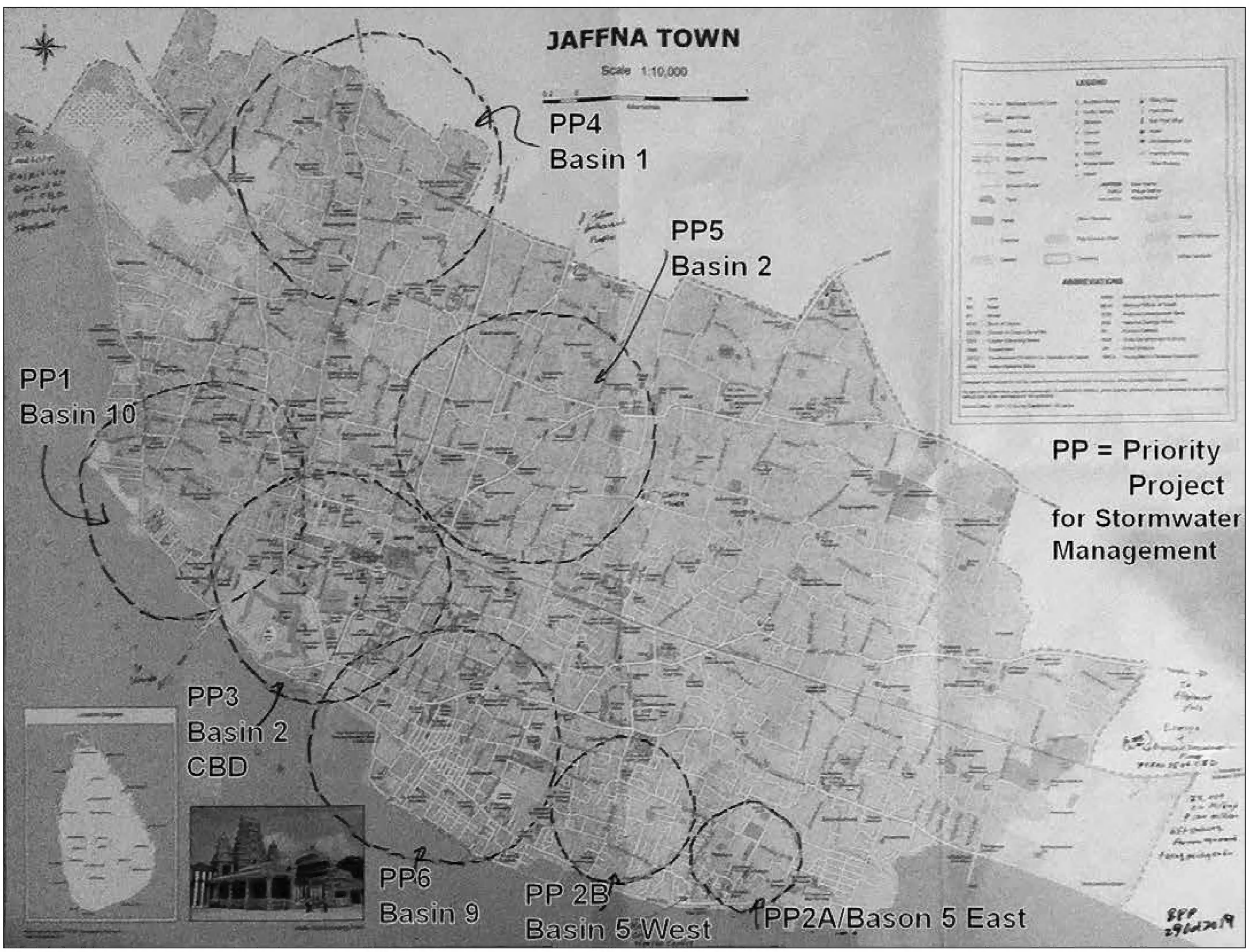

Figure 7 - First draft of Jaffna Town Priority Basins for Stormwater Drainage Management.

However, some flood reduction could be readily achieved by:

1. Cleaning and keeping clean the existing canal, pond, and outlet network;
2. Installing, operating and maintaining rooftop water capture and post-flood release (Fig. 8); and
3. Increasing the storage capacity of the aquifer by blasting and tunneling.

Running the project turned out to be complicated because the client required the team leader to live in and work from the Jaffna House, while the local technical team of part-time, consultants lived and worked in the capital Colombo, 393 kilometers to the south.

An added complication was that Jaffna was at the epicenter of the 30 years long civil war between the minority Tamil-speaking Hindu population and the national government The Civil War devastated Jaffna and left it as the poorest and most neglected region of the country. For example, there is no functional civil airport, and there is an extensive military presence.

The work encountered several technical challenges due to the lack of rainfall and runoff records appropriate for numerical modeling of stormwater drainage. This was overcome somewhat by information provided by community members on the 2014 and 2015 floods, by land and aerial surveys, and by satellite maps.

References

Jaffna District Secretariat, 2019. Statistical Hand Book, Jaffna District.

Jaffna District Secretary, 2018. Sustainable Development of Jaffna District: Five-Year Development Plan, 2018-2022.

MG Consultants, 2019. Assessment of Environmental and Social Baseline Conditions of the Ponds in the Jaffna City Region.

SWS-TECNIC-EML, 2019. Draft Jaffna Storm Water Drainage Master Plan.

UNDP / UN-HABITAT, 2006. Jaffna City Profile.

Water Resource Board, 2017. Consulting Services for Ponds Rehabilitation in Jaffna City Region.

World Bank, 2016. Terms of Reference, Preparation of Master Plan for Storm Water Drainage System of Jaffna City and Preparation of Priority Investment Plan.

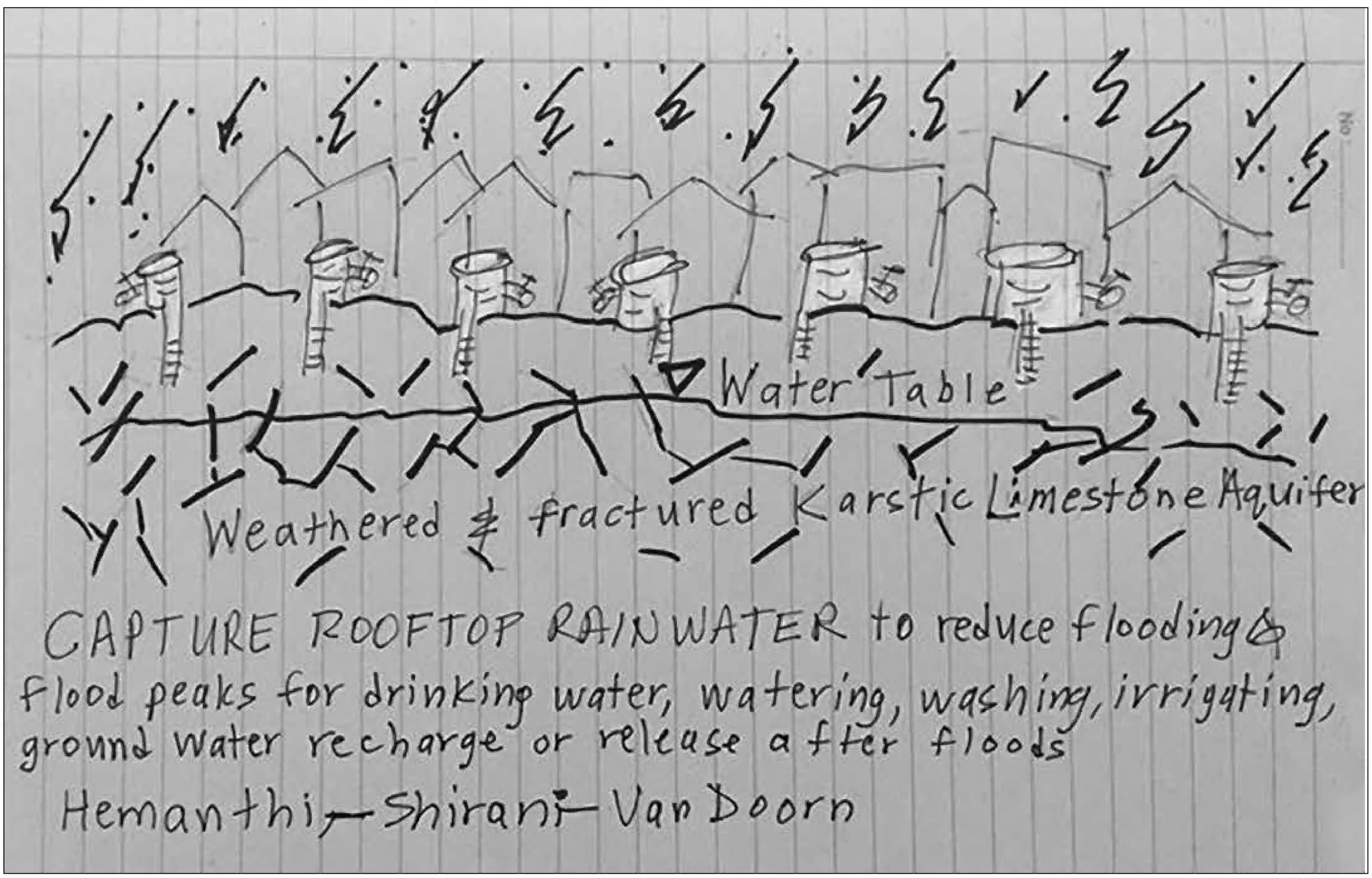

Figure 8 - Schematic of capture of rooftop rainwater to reduce flooding and flood peaks. Drs. Hemanthi and Shirani, and Mr. Van Doorn were senior consultants on the project in Sri Lanka.

Table 1

1. Selected Water Parameters			
		S.I. Units	U.S. Units
Annual Rainfall		11 yeas	2008-2018
Range:		869-1839 mm	34-73 in.
Median		1369 mm	54 in.
Rain Days		4 yrs	2015-2018
Range		48-106 days	
Median		73 days	
Annual Flood Vols.			
2014		1,736,089 m^3	1407 ac-ft
2015		2,247,255 m^3	1822 ac-ft
2. Annual Fresh Water Budget			
Rainfall	*100%*	*1,250 MCM*	*1,013, 393 ac-ft*
Runoff	30%	375 MCM	304,017 ac-ft
Evapotranspiration	**50%**	**625 MCM**	**506,696 ac-ft**
Aquifer Recharge	20%	250 MCM	262,678 ac-ft
3. Annual Fresh Water Use			
Total	*100%*	*169 MCM*	*137,011 ac-ft*
Agricultural	**71%**	**49 MCM**	**97,285 ac-ft**
Munic. & Domestic	29%	20 MCM	39,725 ac-ft
Soil Infiltration Rate			
Sandy regosols & red/yellow calcic regosols		**>42 cm/hr**	**>17 in/hr**
Limestone Aquifer Permeability			
47 rising head field tests			
	Range	~10^{-8} - 10^{-5}ms^{-1}	~0.0028-2.8 ft/day
	Median	10^{-6}ms^{-1}	~0.28 ft/day
40 large-pond infiltration tests			
	Range		~2.12 to 232 ft/day
	Median		~13.2 ft/day
Groundwater level		**0-3 m**	**0 -9.8 ft**
Aquifer thickness		**20 - 30 m**	**66 to 98 ft.**

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